Objectives

- Appropriate use of Doppler for fetal evaluation
- Demonstration of normal fetal Doppler patterns for umbilical artery, middle cerebral artery, ductus venosus and umbilical vein
- Abnormal fetal Doppler patterns – what do they look like and what does the information mean?
- Application in congenital heart disease
Doppler Effect and Blood Flow Velocity

Frequency of the Transmitted Beam

Doppler Frequency Shift

Frequency of the Scattered Beam

Blood flow velocity information

Feasibility of Fetal Doppler Ultrasound: Time Line

Umbilical Vein

Umbilical Artery

Fetal Aorta

Fetal IVC

Fetal Cerebral Artery

Fetal Kidney

Ductus Venosus

1977

1979

1980

1983

1983

1986

1989

1991

FitzGerald

Eik-Nes

Arbeille

Gill

Maulik

Maulik

Veille

Maulik

Vyas

Wladimiroff

Kiserud

Maida

Pourcelot
Arterial Doppler Waveform Analysis
Hemodynamic Basis

Upstream Effect
Downstream Effect

Maulik, Arbeille, Kadado. Biol Neonate, 1992

Doppler Analysis – the Indices

Resistance Index (RI)
Pulsatility Index (PI)
Systolic/Diastolic Ratio (S/D)
Diastolic Average Ratio (D/A)

Maulik et al, 1984

Maulik et al, 1984
P = (S-D)/D (Preust, 1974)
PI = (S-D)/A (Kagey, 1979)
D/A Ratio (Schatz and Drum, 1980)
D/A Ratio (Maulik et al, 1980)
Umbilical Artery Doppler

Absent/Reverse End-Diastolic Flow

Compiled from 1126 reported cases

<table>
<thead>
<tr>
<th>Perinatal Outcome</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perinatal mortality</td>
<td>45%</td>
</tr>
<tr>
<td>Gestational age</td>
<td>31.6 wks</td>
</tr>
<tr>
<td>Cesarean for fetal distress</td>
<td>73%</td>
</tr>
<tr>
<td>Apgar score at 5min &lt;7</td>
<td>26%</td>
</tr>
<tr>
<td>Admission to NICU</td>
<td>84%</td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>10%</td>
</tr>
<tr>
<td>Aneuploidy</td>
<td>6.4%</td>
</tr>
</tbody>
</table>

**Umbilical Artery Doppler in CHD**

- Obstetric complications, e.g. fetal growth restriction
- Increased abnormality in CHD with:
  - Aneuploidy
  - Other malformations
- Isolated CHD
  - Most cases: no specific change
  - Higher UA pulsatility index in right heart obstructive lesions, e.g. pulmonary stenosis, pulmonary atresia, TOF, severe Ebstein’s, tricuspid atresia

Copel et al, JUM, 1999; Ursem et al, UOG 2001; Donofrio et al, 2003; Kaltman et al, UOG,2005

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**Middle Cerebral Artery Doppler**

Arbeille et al, UMB, 1987
**Middle Cerebral Artery Doppler**

- Increased MCA artery end-diastolic flow reflects lower flow impedance – response to in-utero hypoxia
- MCA Doppler / Umbilical artery Doppler ratio (CPR, U/C) reflects flow redistribution - “brain sparing effect”
- High MCA peak systolic velocity indicates fetal anemia


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**Fetal Cerebral Artery Doppler in CHD**

- MCA Doppler in hypoplastic left heart
  - Decreased CV flow impedance
  - Lower MCA Doppler indices
- MCA Doppler in right sided obstructions
  - >> left sided obstructive lesions
  - > normal
- Cerebral Doppler/umbilical Doppler (CPR, U/C)
  - Controversial - ?“brain sparing effect” in CHD
  - Higher (Donofrio 2003) vs. normal (Rychik 2005)
  - ? Predictor of neurological outcome in CHD
Ductus Venosus Doppler

- S = ventricular peak systole
- D = ventricular early diastole
- A = atrial systole
- Venous compliance and reservoir function
- Reflects right heart function

Absent or reverse A wave
- Right heart dysfunction
- Late predictor fetal decompensation
- Independent predictor of mortality in FGR
- Independent predictor of intact survival (neonatal)

Fetal Ductus Venosus Doppler in CHD

- Absent or reverse “A” wave indicates fetal cardiac failure and predicts the outcome including mortality
- Absent or reverse “A” in 1st Trimester predicts 30-40% of euploid CHDs
- Increased peak velocities in severe outflow tract obstructions (HLHS, PS, AS, TOF, Ebstein’s, TV atresia)
- Abnormal DV in CHD with other malformations, aneuploidy, fetal growth restriction
- No significant changes in most cases of CHD
• Advanced fetal decompensation
• Reflects right heart dysfunction with increased right atrial pressure
• Poor prognosis

**Cardiovascular Profile Score**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal</th>
<th>-1 point</th>
<th>-2 point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrops</td>
<td>None (2 points)</td>
<td>Ascites, pleural or pericardial effusion</td>
<td>Skin edema</td>
</tr>
<tr>
<td>Umbilical vein Ductus venosus</td>
<td>No pulsation</td>
<td>No pulsation A wave zero or reversed</td>
<td>Pulsation</td>
</tr>
<tr>
<td>Cardio-thoracic ratio</td>
<td>0.20 &gt; &lt;0.35</td>
<td>0.35-0.50</td>
<td>&gt;0.50 or &lt;0.20</td>
</tr>
<tr>
<td>Cardiac function</td>
<td>Normal TV and MV RV/LV S.F. &gt;0.28</td>
<td>Holosystolic TR or RV/LV S.F. &lt;0.28</td>
<td>Holosystolic MR or TR dP/dt 400 or monophasic filling</td>
</tr>
<tr>
<td>Umbilical artery Doppler</td>
<td>EDV present</td>
<td>AEDV</td>
<td>REDV</td>
</tr>
</tbody>
</table>

TV=tricuspid valve; MV=mitral valve; RV=right ventricle; LV=left ventricle; TR=tricuspid regurgitation; MR=mitral regurgitation; SF=shortening fraction; AEDV=absent end diastolic velocity; REDV=reverse end diastolic velocity.

Huhta et al, JMFNM, 2006
Conclusions

- Fetal Doppler findings in CHD depend on:
  - Associated malformations
  - Aneuploidy
  - Obstetrical complications, e.g. fetal growth restriction, preeclampsia

- Fetal arterial Doppler has selective utility in CHD.
- Fetal venous Doppler has defined utility in CHD:
  - Absent or reverse “A” wave in the ductus venosus indicates fetal heart failure and poor prognosis.
  - Umbilical venous pulsations indicate poor prognosis.

Thank You